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Special Topic: Energy Storage Materials

Search for better materials for rechargeable electric energy storage

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Meeting the energy needs of the world's ever growing population in an environmentally and geopolitically sustainable fashion is among the most important technological challenges facing mankind today. The challenge of and demand for sustainable energy or clean energy have stimulated and catalyzed enormous efforts, resulting in significant progress in the advancement and commercialization of clean energy technologies. Examples include the proliferation of solar cells and wind turbines, but clean energy still generates only a small fraction of the energy we use today.

The intermittent nature of clean energy sources and our modern society's dependence on uninterrupted power source make stable and efficient energy conversion and storage technologies indispensable; the latter can make a significant impact on matching the power supplied by power plants to the oscillating consumption by human activities. Our increasingly mobile life also demands far more than reliable and efficient energy storage technologies. Today's internet and transportation technologies allow us to travel around the world frequently and easily, while fast paced work and social activities require us to remain constantly connected whenever and wherever we are. Portable energy storage technologies are the best sources of power to meet these needs.

Electric power is the most convenient power source, and electric energy storage, particularly rechargeable electric energy storage, is the most important technology for both stationary and mobile applications. It easily explains the longstanding research and industrial fervor for electric energy storage technologies: rechargeable batteries and capacitors. In spite of the huge investment of financial and human capital, the advancement of batteries and supercapacitors has been painstakingly slow, lagging well behind the constant proliferation of other modern technologies. Unlike transistors, there is no Moore's Law for batteries! The biggest hurdle hindering the advancement of rechargeable batteries and supercapacitors lies the materials used in the devices and the interfaces between different materials: electrodes, electrolyte and membranes, additives and binders. Novel materials and solid fundamental understanding are imperative to realizing a revolution of high-energy and high-power electric energy conversion and storage technologies.

This special issue on Materials for Rechargeable Electric Energy Storage includes 4 reviews. Massé *et al.* reviewed the history of intercalation electrodes and basic concepts pertaining to rechargeable batteries based on intercalation reactions. Xin *et al.* focused on the conversion reaction in rechargeable lithium-sulfur and lithium-oxygen batteries. Each provided a comprehensive discussion on the fundamental electrochemistry, critical problems, and recent advancements with the corresponding improvement strategies in key components. Challenges and avenues for further research have been highlighted throughout. Wang *et al.* discussed the different approaches for optimizing energy and power density in electrochemical capacitor electrodes, focusing on the recent developments for redox- and intercalation-based electrode materials. Li and Liu focused on current and future directions reducing the cost and improving the performance of redox flow battery systems. They discuss rational design of organic redox molecules with tailored properties for both aqueous and organic systems, new membranes and separators, and control of the side reactions on the electrode surfaces

Three perspectives offer highly distilled fundamental understanding, recent key advances, and future directions of the respective sub-topic areas. Xu convinces us "being able to manipulate the chemistry and morphology of interphase in batteries, such an important sub-component, holds the key to the success of new batteries." Wen *et al.* pointed out the important future directions and challenges in flexible batteries. Shen *et al.* outlined the progress, challenges and perspectives of polymer nanocomposite dielectrics for capacitors capable of delivering mega- or even gigawatts of power.

Yao highlighted recent investigations on "taming lithium metal through seeded growth," an unexploited approach to precisely control lithium metal nucleation during electrochemical plating. Also included in this special issue is an interview of Prof. Liquan Chen, a pioneer of lithium batteries and lithium ion batteries in China, on his work of the past 40 years and his perspective on the future prospects of solid metallic lithium batteries.

We hope all the papers in this special issue are highly beneficial to wide readership ranging from veterans in the field, to new comers such as graduate students, to general curious readers, and would prepare, promote and provoke new research in rechargeable electric energy storage materials.

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